d. Said invention can be applied to fast transform techniques such as fast Fourier transforms, fast cosine transforms, fast sine transforms, and fast inverse transforms corresponding to each of these, resulting in reduced computational cost.

e. Said invention can exploit the properties of finite-precision numeric representations of numbers, as well as properties that depend on the number values and not on representations in particular formats.

Further objects and advantages of the invention will become apparent from a consideration of the drawings and ensuing description.

DRAWING FIGURES

Fig 1 shows a structure for computing a 4-point discrete Fourier transform

Fig 2 shows the 16-bit twos complement representations of $\sin(2\pi / N)$ and $\sin(4\pi / N)$ for $N = 64$.

REFERENCE NUMERALS IN DRAWINGS

10 a DFT input x[0]
12 a DFT input x[1]
14 a DFT input x[2]
16 a DFT input x[3]
18 a DFT output X[0]
20 a DFT output X[1]
22 a DFT output X[2]
24 a DFT output X[3]
26 a DFT weight 1 + 0j
28 a DFT weight 0 + j

30 a DFT weight -1 + 0j

32 a DFT weight 0 - j

34 a fifth of bit of $\sin(2\pi / 64)$

36 a sixth bit of $\sin(2\pi / 64)$

38 a fourth bit of $\sin(4\pi / 64)$

40 a fifth bit of $\sin(4\pi / 64)$

46 a desired decimal value of $\sin(2\pi / 64)$

48 a desired decimal value of $\sin(4\pi / 64)$

50 a fifteenth bit of $\sin(2\pi / 64)$

52 a sixteenth bit of $\sin(2\pi / 64)$

54 a ninth bit of $\sin(4\pi / 64)$

56 a tenth bit of $\sin(4\pi / 64)$

58 an eleventh bit of $\sin(4\pi / 64)$

60 a twelfth bit of $\sin(4\pi / 64)$

62 a 16-bit decimal value of $\sin(2\pi / 64)$

64 a 16-bit decimal value of $\sin(2\pi / 64)$

DESCRIPTION – SIGNAL PROCESSING TRANSFORMS

Signal processing is widely used in such areas as digital communications, radar, sonar, astronomy, geology, control systems, image processing, and video processing. In digital signal processing, the signals are represented by numbers. Input signals or numbers are manipulated by signal processing transforms to produce output signals or numbers. The input numbers, the output numbers, and intermediate terms take on values from finite sets. The possible values for a particular number are determined by that number's finite-precision numeric format. Additionally, there may be constraints on the allowed values of certain numbers. One example of a constraint is that in discrete Fourier transform weights are known constants. Another example from digital communications is selection of a symbol from a symbol constellation. The symbol constellation may be

very small relative to the set of number values supported by the finite-precision numeric format which the symbol values use.

Arithmetic operations are important tools in signal processing. Two of the most important arithmetic operations are multiplication and addition. A general multiplier is a circuit or a sequence of operations that computes the product of two numbers, each of which can have any value allowed by its finite-precision numeric format. A general adder is a circuit or sequence of operations that computes the sum of two numbers, each of which can have any value allowed by its numeric format.

General multipliers and general adders are useful in signal processing for two reasons. One is that they can be used repeatedly in a particular application or in different applications. A second reason is that there are standard circuits or operation sequences for general multipliers and general adders, so that the designer of a signal processing system does not have to build each multiplier circuit or sequence or adder circuit or sequence separately. A disadvantage of general multipliers is that they are relatively expensive to implement in technologies such as a field-programmable gate array (FPGA), an application-specific integrated circuit (ASIC), or software for a general purpose microprocessor.

Equation (1) defines a one-dimensional N-point signal processing transform that uses both multiplication operations and addition operations. The N inputs of the transform, x[n] for n = 0,1,...,N-1, may be real numbers or complex numbers. The N outputs, X[k] for k = 0,1,...,N-1, are each a sum of products. Each product is a weighted input. Each weight w[n,k] is a number that may be real or complex, depending on the transform. For an arbitrary set of weights, the computational complexity of the full transform may be as high as N^2 general complex multiplication operations and $(N-1)^2$ general complex addition operations. The complexity is thus on the order of N^2 complex operations, or $O(N^2)$ complex operations. A general complex multiplication operation is capable of computing the product of any two complex numbers. A general complex